Pathfinding for Airspace with Autonomous Vehicles (PAAV) + m:N Tabletop

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Outline

- Introduction to the PAAV Project
- PAAV Background – ConOps Perspective
- 2022 PAAV + m:N Tabletop Study
  - Objectives
  - Scope
  - High-Level Topics
  - Participants & Sessions
  - Method
- m:N Group Feedback & Questions

Introduction to PAAV Project

State-Of-The-Art and Needs

State-Of-The-Art

- **UAS-NAS:** DAA and C2 standards enable industry to build certified systems
- **UAS-NAS:** Large UAS flights without a chase aircraft with accommodations
- Industry is developing vehicle autonomy that will need to be integrated into the airspace

Problem

The current air traffic management system is not able to support routine "file and fly" of increasingly autonomous aircraft integrated with current aircraft

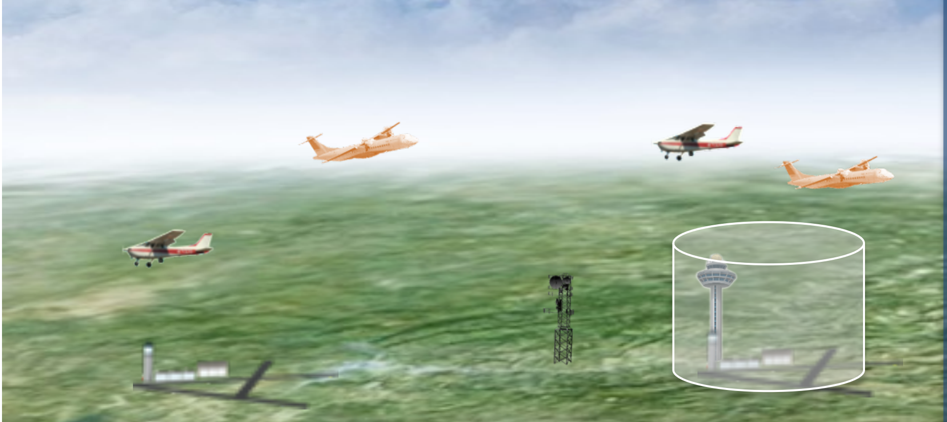
Needs

- A common stakeholder informed concept for airspace integration of operations scalable to future autonomy
- Examination of airspace integration at a systems level
- Airspace procedures and technologies that are scalable to future autonomous operations

PAAV Research Strategy

Regional Operations
(FY22 – FY26)

Scope: Airspace integration of targeted autonomy for **regional** operations in **lower complexity** airspace shared with conventional air traffic



Ex: non-towered airport, Visalia (VIS) Ex: Waco (ACT)

Long Range Operations
(FY26 – FY31)

Scope: Extend previous TC to **longer range** operations in **dense and highly complex** airspace

Ex: Portland (PDX), Dulles (IAD)

Stakeholders and Partnerships

A multi-faceted industry partnership and stakeholder engagement will bring broader resources and participation to fully achieve the project objectives

Stakeholders

- The FAA
- Industry standards organizations (e.g., ICAO, RTCA, ASTM)
- UAS manufacturers
- UAS avionics manufacturers
- Cargo transportation companies

Partnerships

- Industry Partnerships
  - Conduct collaborative flight demonstrations and collect input to ConOps
  - Pursuing Space Act Agreements with potential partners
- FAA Partnerships
  - Pursuing regular engagements with FAA through Technical Interchange Meetings and other and other avenues
- International
  - Collaboration with DLR to advance airspace integration and explore trajectory negotiation for increasingly autonomous aircraft

Technical Approach

Concept of Operations

- Airspace integration use cases
- Community informed ConOps
- Airspace integration guidelines

Use cases and guidelines

Validated via flight demonstrations

Collaborative Flight Demonstrations

- Leverage industry developed autonomy
- Validate technologies for airspace integration
- Verify airspace integration guidelines

Technology Development and Modeling & Simulation

- Evaluate tradeoffs for different airspace integration concepts to inform scalability and system-level impact
- Test airspace technologies and define requirements for increasingly autonomous aircraft in low complexity airspace (e.g., non-towered and Class D)

Lack of Common Airspace ConOps for Autonomous Operations

Aircraft Operator Technologies for ATC Interaction

Natural Language Processing and technologies to enable a supervisory pilot to control multiple unmanned aircraft and manage communications with ATC

Major Challenges: ATC voice communication and clearance implementation latency

Sources: Internal industry ConOps, m:N working group discussions

Collaborative Corridors

Cooperative separation in dedicated corridors that are segregated from conventional air traffic

Major Challenges: Extensibility to the terminal area where autonomous aircraft must merge with conventional aircraft

Sources: FAA BNE, UAM ConOps, Fly Ohio

Self Separation (VFR-Like)

Cooperative services, enhanced DAA, and strategic trajectory management to fly without ATC separation services similarly to how VFR aircraft fly today

Major Challenges: Extensibility to high complexity airspace and IMC

Sources: RTCA DO-304B UAS Cargo ConOps, internal industry ConOps

PAAV will work across stakeholders and conduct trade assessments to define a common ConOps that incorporates relevant aspects from all the concepts above

PAAV Background – ConOps

ConOps Objectives

- ConOps activity is intended to support the following objectives:
  - Develop an **industry-drive ConOps** that reconciles the wide set of business interests, use cases, and operational concepts into an over-arching ConOps that can be used for setting common standards and requirements for the industry
  - Support a gradual introduction of autonomous operations into the NAS with increasing levels of autonomy over time, **starting from remotely piloted or managed operations integrated in current air traffic management structures and progresses** as seamlessly as possible
  - The ConOps will help **define a series of in-depth research activities** to be conducted by NASA to **alleviate key technical and procedural barriers** to the integration of these operations into the NAS

PAAV Technical Challenges

From TC Tollgate: Scope

– **Concept of operations** and **trade assessments** will address gate-to-gate operations at a systems level

– Technology development will focus on the **terminal area**, which is the airspace with the most unresolved challenges

From TC Tollgate: Approach

– **PAAV will work across stakeholders and conduct trade assessments to define a common ConOps that may incorporate relevant aspects from these concepts:**

  - **Cooperative corridors:** cooperative separation within dedicated, segregated corridors
  - **Self-separation (VFR-like):** fly without ATC separation services similarly to VFR aircraft today
  - **Aircraft operator technologies for ATC interaction:** natural language processing and technologies to enable supervisory control of many vehicles and ATC communication

PAAV Technical Challenges

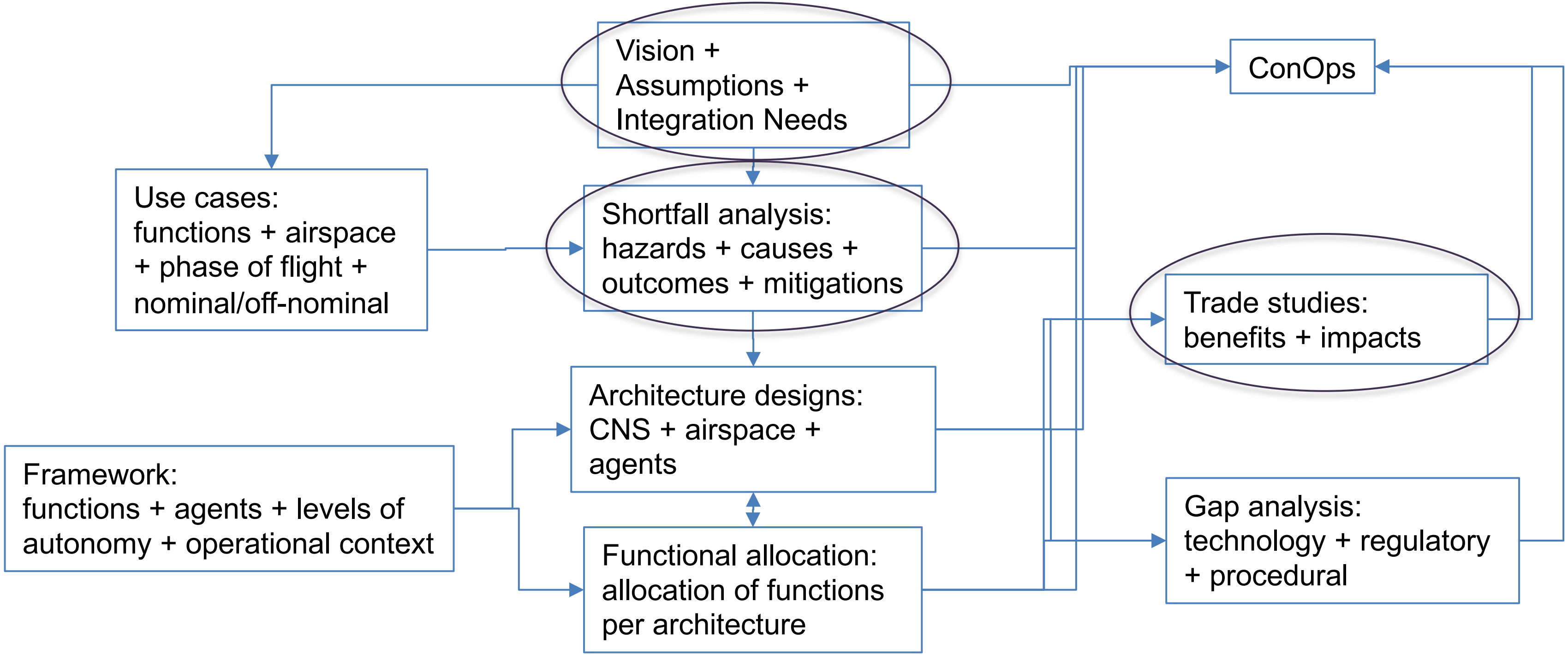
TC Tollgate implications:

– Scope of ConOps is **gate-to-gate**; however, for ConOps trade assessments to support and leverage technology development:
  - Make sure to include **regional terminal** operations
  - Give **priority** to regional terminal operations
  - Ensure concepts and models are **extensible** to **non-regional** TC-2 focus without revamping

– Modeling should leverage existing tools for separation/DAA/ACAS and for C2

– Scope of ConOps includes cooperative separation in corridors, VFR-like operations, and automated ATC interactions for m:N
  - This scope is consistent with current plans to investigate a continuum of autonomy levels

ConOps Development Approach

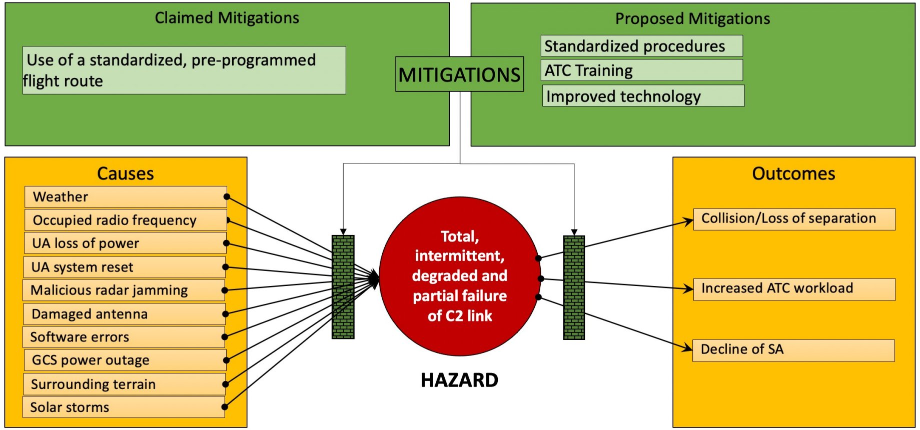


ConOps Assumptions

Possible Initial State Assumptions (in progress)	Possible End State Assumptions (in progress)
Vehicle has **airworthiness certificate**, enabling operation under Part 135	Vehicle has **airworthiness certificate**, enabling operation under 14 CFR
Vehicles will be operated remotely with **one operator per vehicle** and possible handoff between operators	Vehicles are desired to be operated remotely with **multiple (m) operators per multiple (N) vehicles**, via more supervisory operator intervention
Vehicles are equipped with **current CA (TCAS II), DAA (Class 2) and C2 capabilities** for which standards have been largely developed	Vehicles are equipped with **advanced CA, DAA, and C2 capabilities**, including advanced terrain and weather avoidance capabilities
Contingency plans are pre-planned	**Contingency management is automated** with **well-defined human operator role**
UA will fly exclusively under **IFR**	UA will fly **IFR** and leverage **digital and/or visual-like flight rule** behavior where available
Penetration of these operations is limited to **low complexity airspace**, such as classes D, E, and G, serving markets around small **regional airports**	Penetration of these operations is expanded to **more complex airspace and major airports**
Separation services are provided by the **FAA in controlled airspace** and the **IFR UA will mix with VFR traffic in controlled and uncontrolled airspace**, using existing flight rules and conventional means and processes	Airspace services are provided according to the **NAS 2045 vision**, including, for example, more **automation** and **third-party services**
CNS will use conventional methods such as **voice communication between ATC and the ground station** operator using the vehicle voice relay capability, and **conventional surveillance and navigation capabilities** (leveraging satellite and digital technologies as feasible)	CNS will use advanced methods including more **digital communication between ATC and the ground station operator**, leveraging **satellite/cellular/HARS** technologies as feasible, and more advanced **vehicle-to-vehicle communications**
Operations will be conducted in both **nominal and off-nominal conditions**, such as inclement weather and lost link	Operations will be enabled in **off-nominal conditions** such as lost link, inclement weather, and low visibility at airports.

Previous Shortfall Assessments

- Goals
  - Identify potential differences resulting from UA integration, potential impact of these changes on ATC and the NAS, and potential mitigations to impacts
- Method
  - Bowtie risk assessment analysis used to identify potential risks to controllers and associated mitigations (established method used by FAA and ICAO)
  - Conducted one human-factors (Aug 20) and two ConOps tabletop exercises (Apr/Jun 21)
  - **Focused on near-term assumptions (1:1)**
  - One-week long each
  - 10-11 SMEs took part in focus group format
    - 6 controllers – enroute, terminal and tower
    - 2 remote pilots – mission and launch/recovery
    - 2 pilots – commercial and regional
    - 1-2 dispatchers



Shortfall Assessment Results Summary

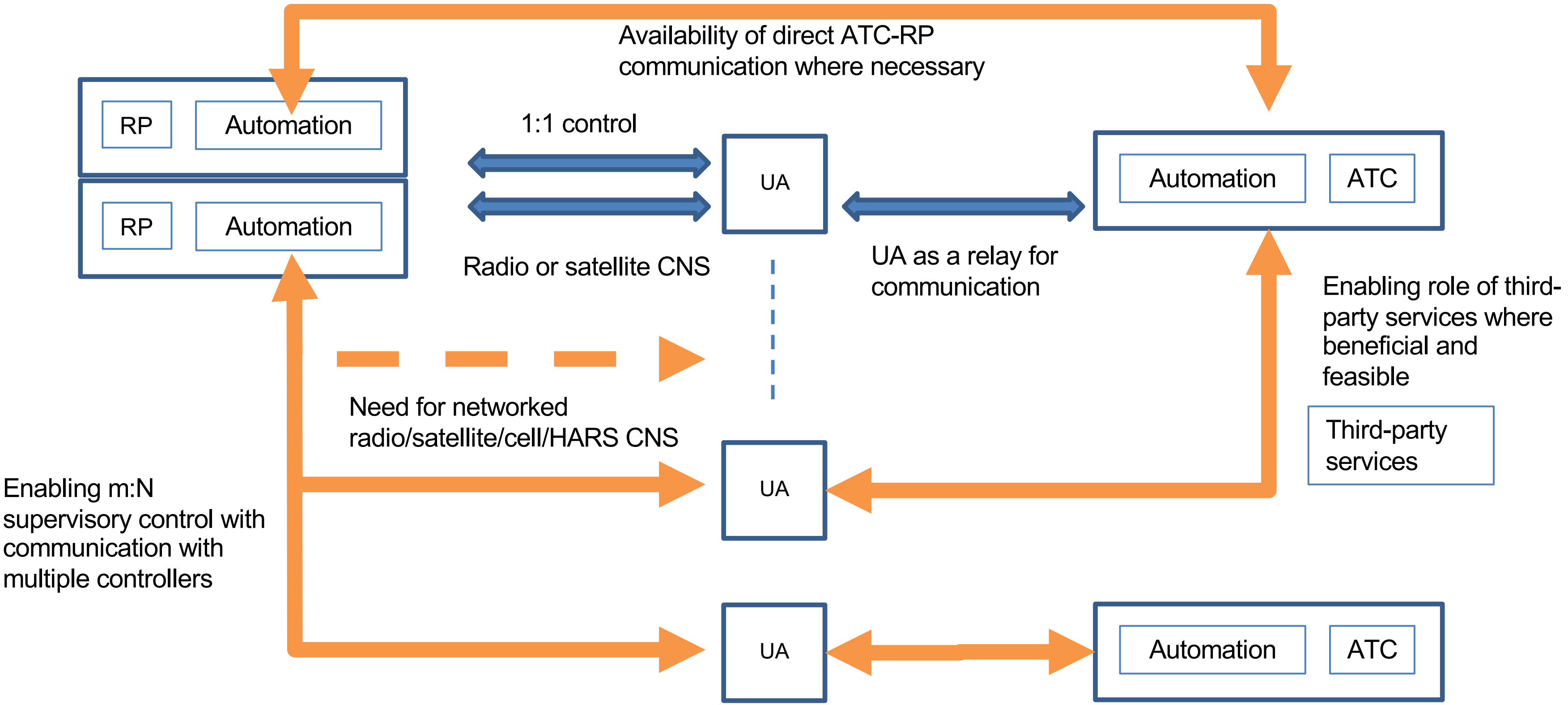
- Results were based on current-day technology and participant responses generated from significant experience in operator roles
  - Findings may not reflect future proposed technologies
  - As newer technologies are considered, the affected hazards and mitigations will be re-evaluated
- Hazards were spread across 8 topics (overlap may exist between them)
  1. Communication latencies – 2 hazards
  2. C2 failure – 4 hazards
  3. Interactions of IFR and VFR – 2 hazards
  4. Detect and Avoid (including lost link) – 8 hazards
  5. Runway operations (including lost link) – 20 hazards
  6. Ramp control operations (including lost link) – 25 hazards
  7. Surface operations (including lost link) – 8 hazards
  8. Off-nominal events and emergencies (including lost link) – 21 hazards

Shortfall Assessment Results Summary (cont.)

- Impact ranged from mild ATC disruptions to critical safety impacts, such as collisions due to undetected conflicts
- Mitigations included
  - Technology –(e.g., UA id, DAA, C2 links, cameras, decision support, …)
  - Training – for controllers, pilots, and dispatchers
  - Procedures – (e.g., for lost link)
  - Simulation HITL guidance
- Publications:
  - PAAV deliverable includes report and several appendices with collected data in table format (may be turned into NASA Technical Memo)
  - Aviation 2021 paper focused on first human factors table-top analysis (by Tamsyn Edwards and team)
  - Aviation 2022 (submitted abstract) focused on ConOps table-top analyses (by Tamsyn Edwards and team)
- Rolled hazards into high-level architectural and functional shortfalls

ConOps Architectural Shortfalls

Expanding to far-term assumptions (in progress)

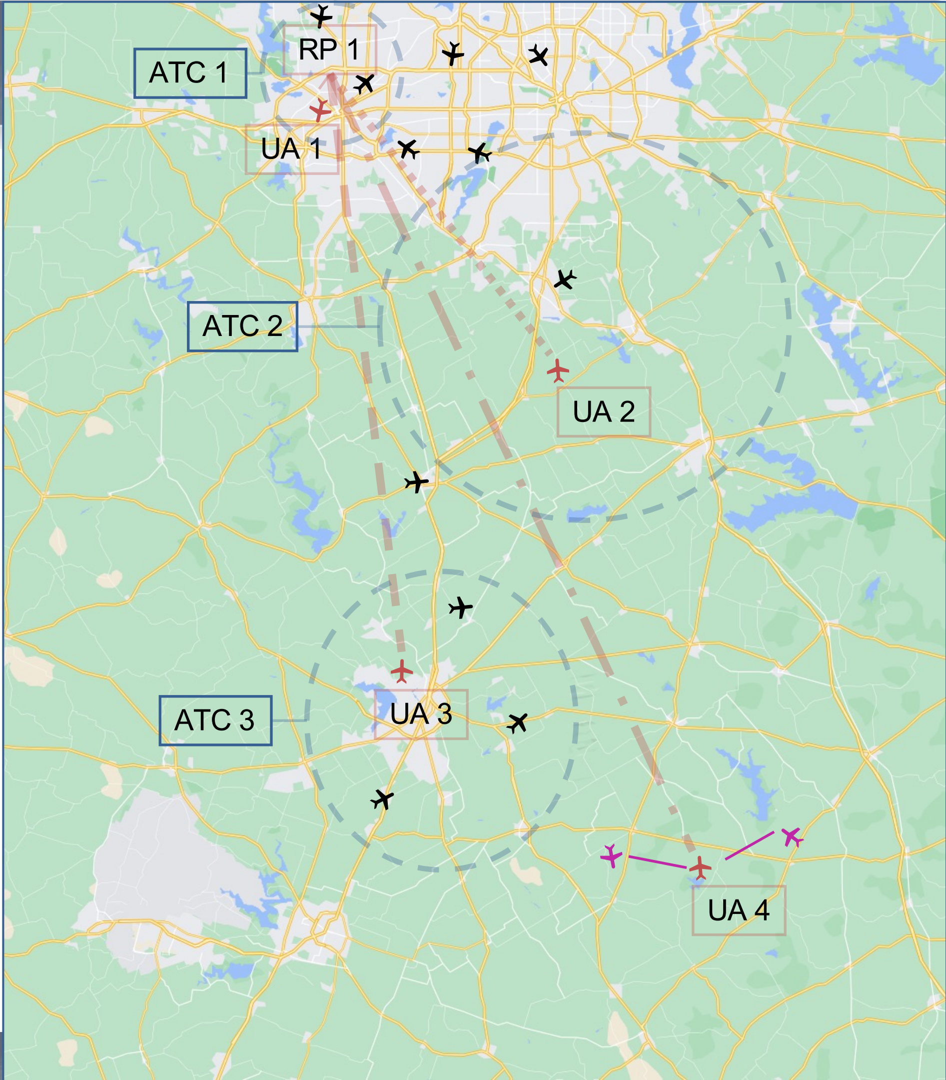


ConOps Architectural Shortfalls

Expanding to far-term assumptions
(m:N example in progress)

For RP 1 located at KAFW:

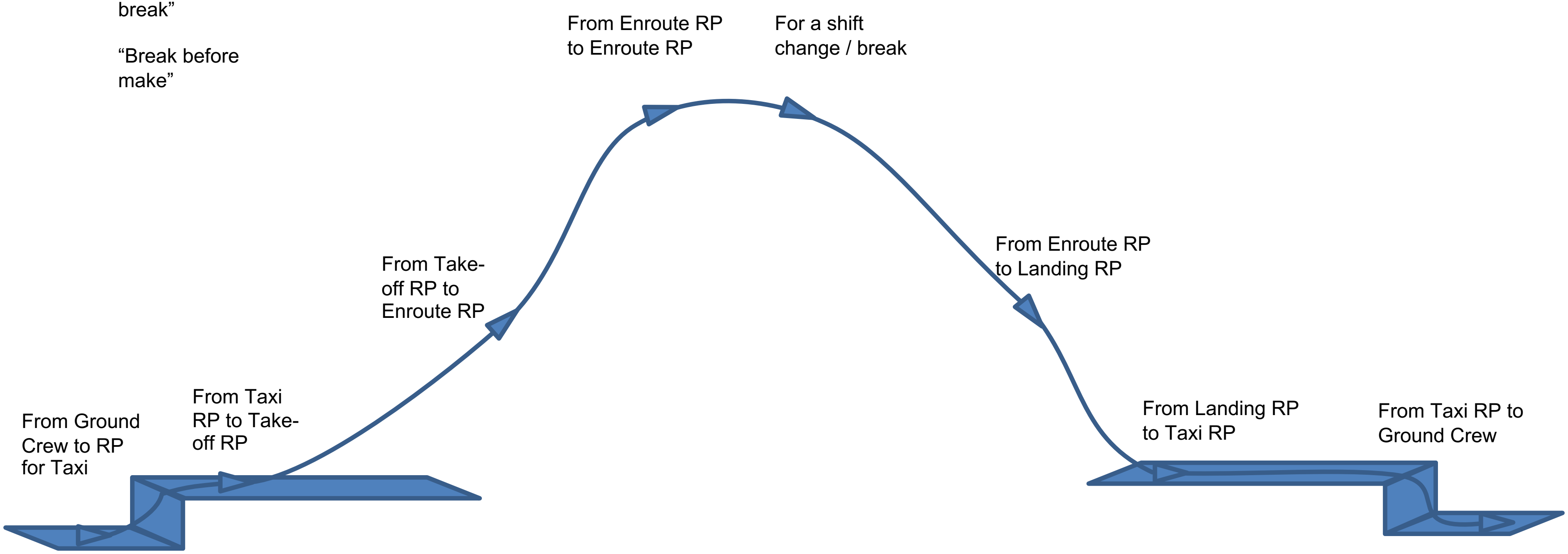
- Number of UA controlling, $N_m(t) = 4$
- Up to 4 different C2 link systems
  - UA 1: Cellular
  - UA 2: Terrestrial
  - UA 3: Low altitude SatCom or HARS
  - UA 4: High altitude SatCom
- There are 3 different ATC sectors
- RP 1 is communicating with 3 different ATCO and communicating on a party line for UA 4
- Level of traffic cooperation
  - high for aircraft near UA 1-3
  - potentially low for aircraft near UA 4



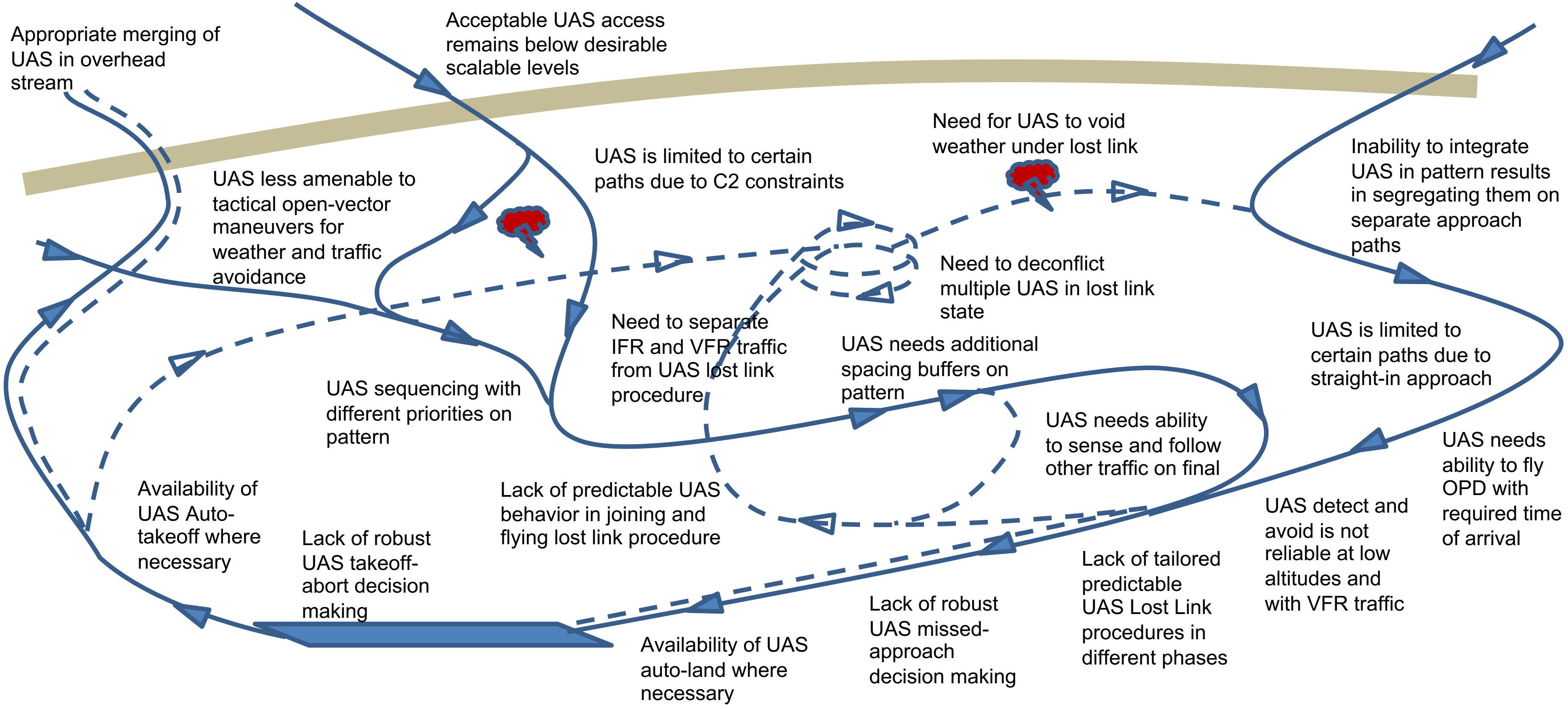
Possible Types of RP Hand-offs

“Make before break”

“Break before make”



ConOps Functional Shortfalls



2022 PAAV + m:N Tabletop

2022 PAAV + m:N Tabletop

Objective

Solicit subject matter expertise:

1) To identify <u>solutions</u> to the <u>barriers</u> for far-term (i.e., m:N) integration of unmanned cargo operations (Large UAS) into the NAS.

2) To identify <u>gaps</u> in technology or procedures that obstruct those <u>solutions</u>.

Execution projected for May 2022

- Remote participation via Microsoft Teams
- Recorded sessions

Scope

Focus Topic Areas

- Separation
- Sequencing
- TMI
- Contingency management

Additional Considerations

- Phase of flight
- Control environment
- Pilot tasks
- m:N
- Level of automation
- Level of distribution

Scope

Focus Topic Areas
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Additional Considerations
- Phase of flight
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- Pilot tasks
- m:N
- Level of automation
- Level of distribution

Phases of flight
- Preflight
- Surface Operations
- Runway operations, takeoff, initial climb
- Enroute
- Descent and approach
- Landing and runway operations

2022 PAAV + m:N Tabletop

Preflight (Standing)
- Crew Responsibilities
- Checklists

Surface Operations (Pushback, Towing, Taxi)
- Taxi with Ramp Control
- Hold Short
- Following traffic
- No Operating Control Tower

Runway Operations (Takeoff, Initial Climb)
- Departure
  - Nominal
    - C2LL
    - Rejected T/O
  - Position and Wait
  - TMI
    - Ground Stop
    - GDP

Weather Avoidance (Enroute)
- Nominals
  - SWAP
  - Pilot Initiated
  - C2LL
- IFR/IFR – **B/C**
- Traffic avoidance – **B/C, E, D**
  - DAA separation
  - ATC separation

Descent and Approach
- Nominal
  - C2LL – **B/C, E, D**
- TMI
  - Metering/MIT – **B/C**
  - Holding – **B/C**
  - C2LL – **B/C**
- Diversion – **B/C**
- Resequencing (TRACON) – **B/C**
- Follow aircraft – **B/C**
- Traffic avoidance – **B/C, E, D**
  - DAA encounter
  - Traffic advisory
- Terrain & obstacle avoidance
- Go Around – **B/C**
  - C2LL – **B/C**
- Missed Approach – **B/C, D**
- Pattern Entry – **D**

Runway Operations (Landing)
- Landing
  - Nominal
    - C2LL
  - LAHSO
  - Low Visibility (Cat 3)
- W/O Operating Control Tower

Informs

m:N
- Situational Awareness
- Prioritizing Control Actions
- Frequency Management
- Data Link Management
- Contingency Management
- GCS Layout & Management
  - Position Relief
  - Transfer of Control
  - Crew Responsibilities
  - Display Management
- Pilot Workload

Other
- Autonomous Actions
  - Landing
  - Taxi
  - RA response
  - TAWS

Example High-level Topics by Phase of Flight

Preflight

Surface Operations

- TMI
- Contingency management

Runway operations, takeoff, initial climb

- TMI
- Sequencing
- Contingency management

Enroute

- Separation
- TMI
- Contingency management

Descent and approach

- Separation
- Sequencing
- Contingency management

Landing and runway operations

- TMI

TMI = Traffic Management Initiatives

Participants & Sessions

Session 1 – Pilots (N = 5-8)
- Regional Cargo Pilots
- RPAS
- RPAS with m:N exposure (if available)

Session 2 – ATC (N = 3-6)
- Class B Tower Controller
- TRACON Controller
- Center Controller

Session 3 – Pilots & ATC
- Same individuals as Sessions 1 and 2

Session 4 – Other experts
- FAA representatives
- Industry stakeholders
- Academics & Researchers
- CNS SMEs

Session 1 = 3 - 4 days

Session 2 = 3 - 4 days

Session 3 = 1 - 2 days

Session 4 = 1 - 2 days

Method – Sessions 1 & 2 (first with Pilots and then ATC participants)

First Day

- Intent of the activity
- Introduction to PAAV and m:N concepts
- Target assumptions for the activity
  - Vehicle/GCS capabilities
  - Level of automation/control distribution
- Exercise to promote flexible and creative thinking

Days 2+

- Phase of flight example narrative based on 1:1 assumptions
- Pause points to divert discussions to specified topic areas of interest
- Revisit phase of flight while, in turn, considering control environment, m:N, controlling or piloting tasks, level of automation and level of …

Last Day

- Revisit assumptions and solutions, including specific m:N topics of interest

Method – Part 2

Session 3 (Same Pilot and ATC Participants return)

- Discuss participant-identified technological or procedural solutions and the barriers they are intended to mitigate

Session 4 (Other experts)

- Out-brief of initial results and identified solutions
- Feedback to contribute to future project activities

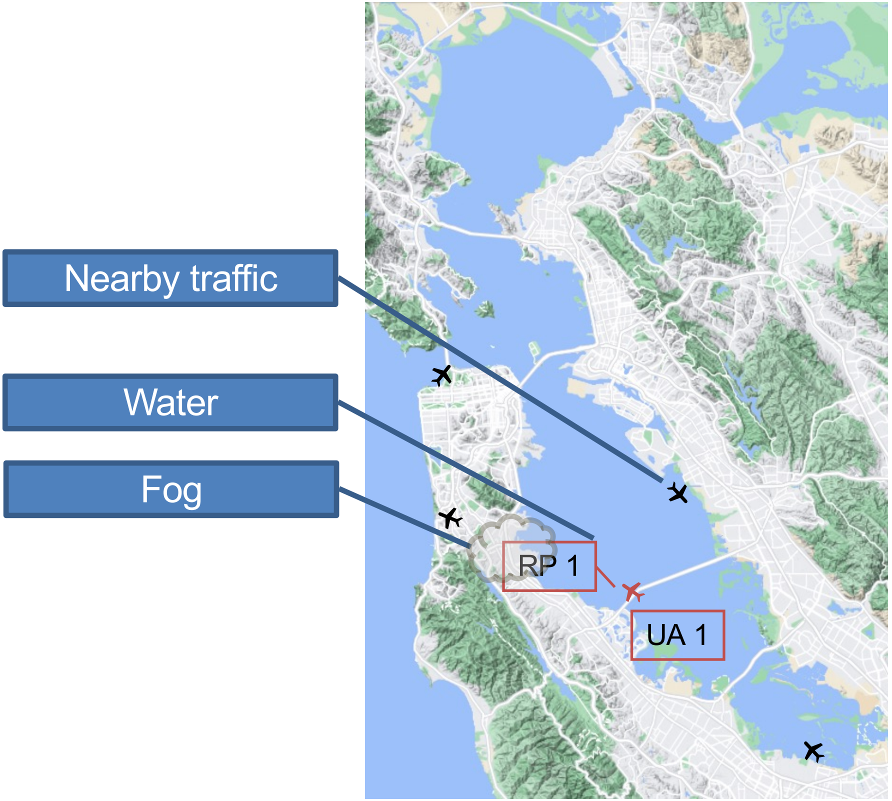
Feedback?

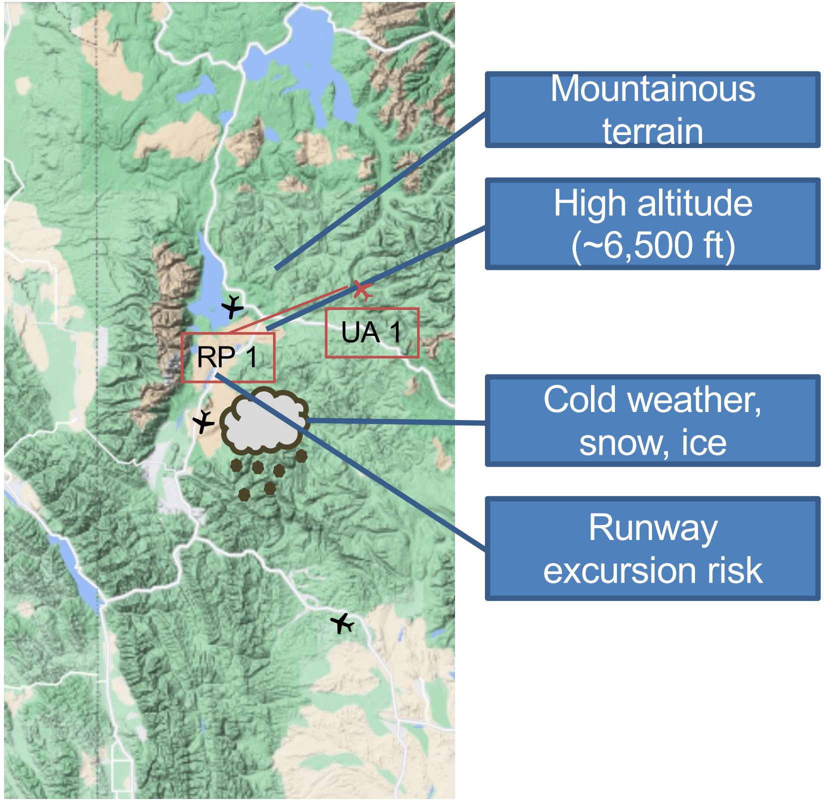
Questions?

Extra Slides

-May or may not include in final presentation

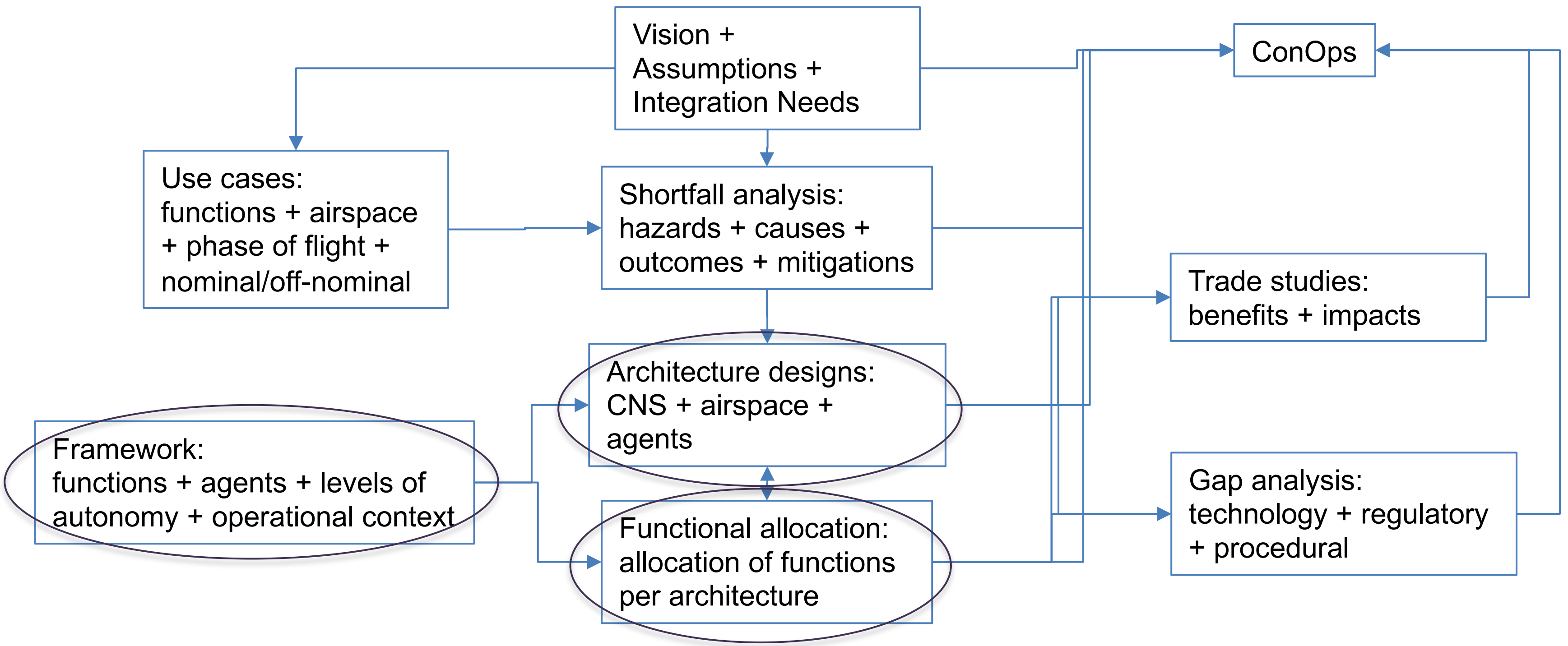
Exogenous Operational Considerations: Terminal





PAAV ConOps Framework

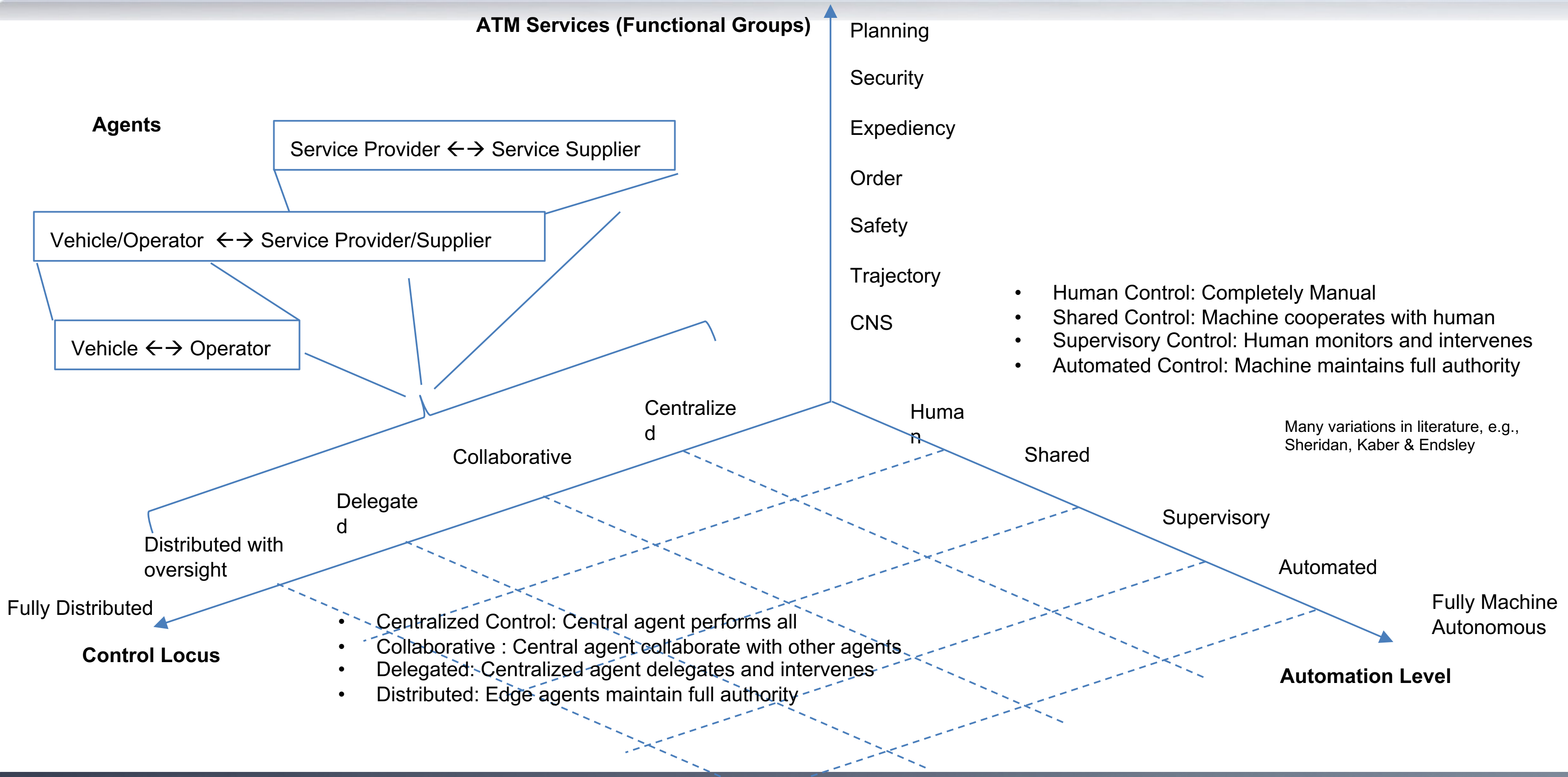
ConOps Development Approach



Motivation

- Want to consider a continuum of autonomy – various levels of responsibilities and automation operating within the same airspace
- Necessitates a decomposition and abstraction of the functions required for achieving the goals of safe, orderly, expeditious, and secure flow of air traffic
  - These functions need to be carried out regardless of how the plane is operated (pilot on board, remotely piloted, remotely supervised, automated, 1:1, m:N, etc.),
  - Regardless of which agent performs a function (vehicle, remote pilot, controller, etc.), and
  - Regardless of whether a human or automation performs a function
- Framework supports interdependency between architecture design and functional allocation. Many of these functions will be allocated differently based on the architecture, or how the unmanned aircraft system(s) is set up and controlled
- Framework supports dynamic functional allocation – dynamic allocation of functions is needed depending on changing flight and airspace conditions as well as architectures

Autonomy Dimensions: Operational



- Human Control: Completely Manual
- Shared Control: Machine cooperates with human
- Supervisory Control: Human monitors and intervenes
- Automated Control: Machine maintains full authority

Many variations in literature, e.g., Sheridan, Kaber & Endsley

- Centralized Control: Central agent performs all
- Collaborative : Central agent collaborate with other agents
- Delegated: Centralized agent delegates and intervenes
- Distributed: Edge agents maintain full authority

Separation Function Example: ATC vs UAS (UAS = RP+UA)

Automation →

Distribution ↓

	Human	Shared	Supervisory	Automated
Central	(1) ATC performs all separation tasks	(2) Automation assists ATC but cannot act w/o ATC	(3) Automation can act w/o ATC but ATC can take over	(4) Automation acts w/o ATC and ATC cannot take over unless invited by automation
Shared	(5) RP assists in separation tasks but cannot act w/o ATC	(6) Automation assists ATC/RP but cannot act w/o ATC/RP – UAS cannot act w/o ATC	(7) Automation can act w/o ATC/RP but ATC/RP can take over – UAS cannot act w/o ATC	(8) Automation acts w/o ATC/RP and ATC/RP cannot take over unless invited by automation – UAS cannot act w/o ATC
Delegated	(9) RP performs separation tasks and can act w/o ATC, but ATC can take over tasks	(10) Automation assists ATC/RP but cannot act w/o ATC/RP – ATC can take over tasks	(11) Automation can act w/o ATC/RP but ATC/RP can take over – ATC can take over tasks	(12) Automation acts w/o ATC/RP and ATC/RP cannot take over unless invited by automation – ATC can take over tasks
Distributed	(13) RP performs separation tasks and ATC cannot take over unless invited by RP	(14) Automation assists ATC/RP but cannot act w/o ATC/RP – ATC cannot take over unless invited by UAS	(15) Automation can act w/o ATC/RP but ATC/RP can take over – ATC cannot takeover unless invited by UAS	(16) Automation acts w/o ATC/RP and ATC/RP cannot takeover unless invited by automation – ATC cannot takeover unless invited by UAS

Process for Allocation

- Determine Use Cases (function + architecture + operational context)
- Determine the possible allocation of function given architecture and operational context, according to autonomy levels
- Rank possible allocations according to criteria such as time criticality, task complexity, etc.
- Repeat function allocation process under different architectures and operational contexts

Functional Allocation Process: Separation Example ATC vs UAS (UAS = RP+UA)

Use case: Separation, with 1:1, under nominal, controlled airspace.

Automation

	Human	Shared	Supervisory	Automated
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Distributed	(13) RP performs separation tasks and ATC cannot take over unless invited by RP	(14) Automation assists ATC/RP but cannot act w/o ATC/RP – ATC cannot take over unless invited by UAS	(15) Automation can act w/o ATC/RP but ATC/RP can take over – ATC cannot takeover unless invited by UAS	(16) Automation acts w/o ATC/RP and ATC/RP cannot take over unless invited by automation – ATC cannot takeover unless invited by UAS

Distribution

Functional Allocation Process: Separation Example ATC vs UAS (UAS = RP+UA)

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Automation

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Functional Decomposition

- Functional decomposition: decomposing objectives, which need to be performed regardless of architecture, into their abstract functions and subfunctions.
- Utilize the IISA process (variant of OODA) to break down objectives.
  - <u>Information acquisition:</u> acquisition of information needed to perform the function.
  - <u>Impact assessment:</u> assessment of impacts requiring mitigation based on performance metrics.
  - <u>Solution planning:</u> computation of solutions to mitigate the identified impacts.
  - <u>Action implementation:</u> implementation of computed solutions by performing the needed actions.

- Function
  - Information Acquisition
    - Subfunction 1
    - …
    - Subfunction N
  - Impact Assessment
  - Solution Planning
  - Action Implementation

IISA Process: Separation Example

(1) ATC performs all separation tasks
(2) Automation assists ATC but cannot act w/o ATC

- **Information Acquisition**
  - What information related to the conflicts with UAS does ATC lack and how can automation provide such information?
  - Example: ATC may not be informed about UAS delays in response time. Automation may assist by providing this information.
- **Impact Assessment**
  - What impacts related to the conflicts with UAS may ATC assess poorly and how can automation help improve assessments?
  - Example: ATC may not detect conflicts with UAS in a timely manner given latency. Automation may assist by detecting conflicts with UAS earlier or with larger buffers
- **Solution Planning**
  - What decision may ATC take that will be deficient with respect to UAS conflict resolution and how can automation help?
  - Example: ATC may assume UAS can maneuver as quickly as other aircraft. Automation can help by prioritizing maneuvering non-UAS, by providing a closed trajectory solution that has a return to the original path avoiding uncertainty in case of a lost link, or by suggesting larger buffers where there is a higher potential for latency and link intermittency.
- **Action Implementation**
  - How may ATC implementation of conflict resolutions be deficient for UAS and how may automation assist with better implementation and execution?
  - Example: ATC may use voice to deliver resolution instructions to the RP. Automation may assist by providing digital delivery of instructions to the RPAS.

IISA Process: Separation Example

(3) Automation can act w/o ATC but ATC can take over

- Automation performs all IISA tasks in (2) and delivers resolution instructions using data communication without ATC input
  - For UAS conflicts only or for all conflicts?
- ATC monitors automation behavior and can intervene by overriding the resolution for a particular conflict or by reducing the automation level and taking over as in (2)

(4) Automation acts w/o ATC and ATC cannot take over only provides oversight

- Automation performs all IISA tasks in (2) and delivers resolution instructions using data communication without ATC input
- ATC monitors automation behavior and cannot intervene unless automation invited ATC to do so
- If invited, ATC intervenes by overriding the resolution for a particular conflict or by reducing the automation level and taking over as in (2) (or as indicated by the automation)

Functional Allocation Process: Separation Example ATC vs UAS

Use case: Separation, with 1:1, under nominal, controlled airspace.

Automation

	Human	Shared	Supervisory	Automated
Central	(1) ATC performs all separation tasks	(2) Automation assists ATC but cannot act w/o ATC	(3) Automation can act w/o ATC but ATC can take over	(4) Automation acts w/o ATC and ATC cannot take over unless invited by automation
Shared	(5) RP assists in separation tasks but cannot act w/o ATC	(6) Automation assists ATC/RP but cannot act w/o ATC/RP – UAS cannot act w/o ATC	(7) Automation can act w/o ATC/RP but ATC/RP can take over – UAS cannot act w/o ATC	(8) Automation acts w/o ATC/RP and ATC/RP cannot take over unless invited by automation – UAS cannot act w/o ATC
Delegated	(9) RP performs separation tasks and can act w/o ATC, but ATC can take over tasks	(10) Automation assists ATC/RP but cannot act w/o ATC/RP – ATC can take over tasks	(11) Automation can act w/o ATC/RP but ATC/RP can take over – ATC can take over tasks	(12) Automation acts w/o ATC/RP and ATC/RP cannot take over unless invited by automation – ATC can take over tasks
Distributed	(13) RP performs separation tasks and ATC cannot take over unless invited by RP	(14) Automation assists ATC/RP but cannot act w/o ATC/RP – ATC cannot take over unless invited by UAS	(15) Automation can act w/o ATC/RP but ATC/RP can take over – ATC cannot takeover unless invited by UAS	(16) Automation acts w/o ATC/RP and ATC/RP cannot take over unless invited by automation – ATC cannot takeover unless invited by UAS

Distribution

IISA Process: Separation Example

(2) Automation assists ATC but cannot act w/o ATC
(6) Automation assists ATC/RP but cannot act w/o ATC/RP – UAS cannot act w/o ATC

- **Information Acquisition**
  - What information related to separation does ATC lack and how can the RP provide such information? How can the RP obtain reliable information?
  - Example: ATC may not be informed about UAS delays in response time. RP may inform ATC about their response limitations (especially if operating many vehicles).
- **Impact Assessment**
  - What impacts related to the conflicts with UAS may ATC assess poorly and how can the RP help improve assessment?
  - Example: ATC may not detect conflicts with UAS in a timely manner given latency. RP can assist with detecting conflicts with their UA and informing ATC.
- **Solution Planning**
  - What decision may ATC take that will be deficient with respect to UAS conflict resolution and how can the RP help?
  - Example: ATC may assume UAS can maneuver as quickly as other aircraft. RP can assist by computing preferred and more robust resolutions for their UA and proposing them to ATC.
- **Action Implementation**
  - How may ATC implementation of conflict resolutions be deficient and how can RP help?
  - Example: RP requests a maneuver from ATC to resolve the conflict instead of ATC sending clearance.

IISA Process: Separation Example

(10) Automation assists ATC/RP but cannot act w/o ATC/RP – ATC can take over tasks

- The RP performs all IISA tasks in (5) and delivers resolution instructions using C2 link without ATC input
- ATC monitors RP behavior and can intervene by overriding the resolution for a particular conflict or by reducing the delegation level and taking over as in (5)

(14) Automation assists ATC/RP but cannot act w/o ATC/RP – ATC cannot take over unless invited by UAS

- The RP performs all IISA tasks in (5) and delivers resolution instructions using C2 link without ATC input
- ATC monitors RP behavior and cannot intervene unless RP invited ATC to do so
- If invited, ATC intervenes by overriding the resolution for a particular conflict or by reducing the delegation level and taking over as in (5) (or as indicated by the automation)

Allocation Criteria

<u>Example Considerations:</u>

- Expertise Level
- Time Criticality
- Uncertainty Level
- Complexity Level
  - Experienced Complexity
  - Information Processing Complexity
  - Problem Space Complexity
  - Lack of Structure Complexity
  - Objective Complexity
- "-ilities"
  - Reliability
  - Availability of functionality
  - Security
  - Safety
  - …
- Outside Factors

Time to conflict

Cooperation level of traffic
Link reliability
…

Separation Example: Dynamic Allocation due to Time Criticality (Time to Conflict)